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SELF RECOGNITION AND SOCIAL AWARENESS IN THE DECONNECTED MINOR HEMISPHERE

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Abstract—Two patients with cerebral commissurotomy were tested with visual input lateralized to left or right half of the visual field by an opaque hemifield screen set in the focal plane of an optical system mounted on a scleral contact lens which allowed prolonged exposure and ocular scanning of complex visual arrays. Key personal and affect-laden stimuli along with items for assessing general social knowledgability were presented among neutral unknowns in visual arrays with 4–9 choices. Selective manual and associated emotional responses obtained from the minor hemisphere to pictures of subject's self, relatives, pets and belongings, and of public, historical and religious figures and personalities from the entertainment world revealed a characteristic social, political, personal and self-awareness comparable roughly to that of the major hemisphere of the same subject.

INTRODUCTION

THE QUALITY and level of conscious experience in the disconnected minor hemisphere of patients who have undergone compiete surgical section of the forebrain commissures and the implications involved for mediation of conscious awareness in the intact brain have remained for some years a matter of speculation and controversy. Whereas conscious function in the disconnected left, language-dominant hemisphere is relatively easy to determine through direct verbal communication, the subjective experience of the predominantly mute and agraphic minor right hemisphere can only be inferred more indirectly through nonverbal, mainly manual, responses that are subject to varied interpretation. On the basis of a wide variety of lateralized test performances we have long favored the view that the disconnected hemispheres in both animal and human subjects are separately conscious in parallel at a moderately high and approximately equal level [1–3].

Direct proof for this interpretation is lacking, of course, and alternative conclusions have been proposed. In some instances it has seemed preferable to conceive the minor hemisphere as a high order, unconscious, computer-like control system or automaton with consciousness centered either in the left hemisphere alone, in the intact brain stem, or in the person as a whole [4–6]. At the opposite extreme, the presence of duplex right and left domains of consciousness has been inferred not only after surgical disconnection, but also in the normal intact state [7–10]. Various intermediate alternatives between these extremes have also been recognized [3, 11, 12].

Contentions that the minor hemisphere is wholly lacking in conscious awareness have largely given way in recent years to a modified position which concedes that the right hemisphere may possess elemental forms of subjective awareness but denies the presence in the minor hemisphere of the higher reflective self-conscious type of mental awareness that characterizes the human brain and which is needed, so it is said, to qualify a system as a person [13]. Self-consciousness appears to be almost strictly a human attribute, according to present evidence drawn mainly from mirror self-recognition tests [14]. It seems not

to be found in animals below the primates, and only to a limited extent in the great apes. In human childhood self-consciousness makes its appearance relatively late in development, appearing first at around 18 months of age [15]. Thus, ontogenetically as well as phylogenetically self-consciousness can be rated as a relatively advanced stage of conscious awareness.

The present study was designed to investigate further the quality and level of awareness in the minor hemisphere of commissurotomy subjects by applying projective tests aimed particularly at aspects of self-consciousness and general social awareness. The results appear to indicate that the concept of self and general social awareness are both present and well developed in the disconnected minor hemisphere exhibiting a level of evolvement essentially comparable to that found in the language dominant hemisphere. A preliminary account of the initial results was presented earlier [16].

METHOD

Subjects, testing and procedure

Two patients (NG and LB) who had undergone the complete forebrain commissurotomy of P. J. Vogel in 1963 and 1965, respectively [17], were selected for study because they appear to have had least damage to extracommissural systems and because each had already been fitted for previous studies with a scleral contact lens on the dominant (right) eye [18]. The scleral lens carries a small optical system with an opaque screen in the focal plane of the visual field that moves with the eye and blocks out the desired half field of vision wherever the gaze is directed. Visual input is thus restricted to the chosen hemisphere while permitting prolonged examination of stimulus material with free scanning movements of the eyes. Both subjects were right handed and had undergone extensive lateralized testing of hemispheric functions for 8–10 yr. Details of the case histories have been presented elsewhere [17].

Testing procedure involved presentation of a choice array of 4 to 9 items consisting of pictures, line drawings, printed or written material, or photographs arranged on a card 25 × 25 cm for visual inspection by the subject while vision was confined by the contact lens occluder to the desired left or right half visual field. The general set-up is illustrated in Fig. 1. Key test pictures for which the subject might have some familiarity, preference, or an emotional response were inserted irregularly among neutral items. The stimuli included photos of the subject's self, family, relatives, acquaintances, pets, belongings, samples of subject's writing, familiar scenes, objects, emblems, and pictures of public, historical and religious figures, entertainers, etc. Introduction of each choice array was accompanied by leading remarks and questions by the examiners often slanted in order to establish desired mental sets and associations as a context for particular items on the choice card. It is assumed that both hemispheres hear and comprehend the verbal instructions and remarks but that only one hemisphere has the visual information needed for an appropriate response

The subject was requested to point with the hand to one or more select items in the choice array that he or she might recognize, would most like or dislike, or might select for a given situation or reason. Subjects were often asked to evaluate by "thumbs-up" or "thumbs-down" gestures his or her feelings about particular items, etc. Subjects' responses included also differential emotional expressions, exclamations, and remarks relative to the affect-laden items and to the testing situation in general. With left field vision these remarks emanated in large part from the vocal hemisphere after affective components of the subject's reaction to the stimulus had crossed the midline centrally. Responses obtained from the right hemisphere through the left field of vision were compared with those obtained from the left hemisphere via the right visual field and also in some cases with those obtained with free unrestricted vision.

Follow-up oral questioning by the examiners was directed to the language hemisphere as a control check for right hemisphere responses when it became important to determine that information about stimulus input to the right hemisphere had not crossed and become available to the left hemisphere. Accuracy of the identification following a manual selection and the subjective semantic structure of the chosen stimuli were further determined by subject's responses to a series of categorizing cues presented in oral questioning or occasionally as a printed list for visual inspection by the right hemisphere. Previous experience with these patients has established that reliable "yes–no" answers can be elicited in response to questions about left visual field material.

A series of 50 choice array cards was prepared each containing at least four test items obtained variously from magazines, newspapers, direct photography and other sources. Care was taken that target items did not stand out in a given array by virtue of purely visual or other irrelevant qualities. Ten of the 50 array cards contained items personally relevant to one subject only and were not used except as neutral controls for the other subject. More than one question and response was regularly obtained from a single card.

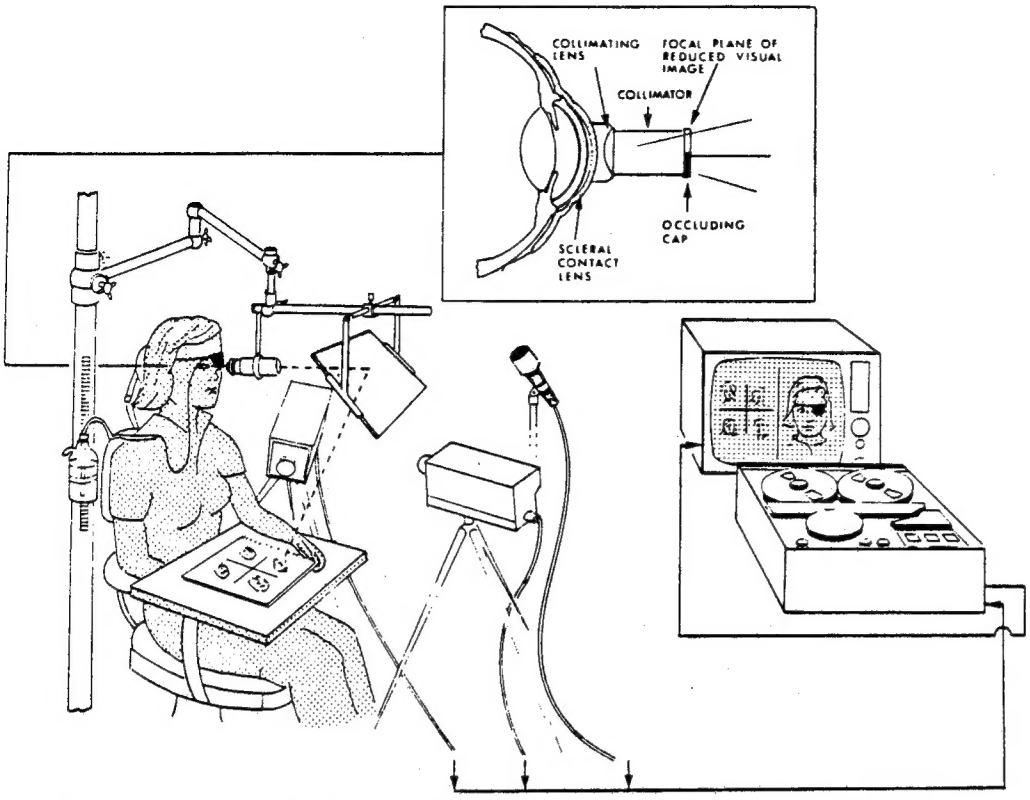

FIG. 1. Apparatus: With vision restricted to one half visual field, subject points to select items in a visual choice array in answer to examiner's oral questions. Audiovisual tape recordings include correlated emotional expression and verbal comments.

Among the 40 test cards for each subject occasional interchanges were made between individual items at different testing sessions for purposes of effecting desired mental associations in a given sequence. A single test session usually lasted from 20 to 30 min and included presentation and multiple responses from 20 to 25 cards. Cards were presented first to the right hemisphere. Repetition of a card sequence to the opposite (left) hemisphere might be carried out within a week, but successive sessions with the right hemisphere, because of the overlap in test material, were spaced many weeks or months apart. A total of more than 200 test responses was obtained from each subject over a 2-yr period starting in 1973. Complete audio tape and, in one session with each subject, audio-visual records were made along with notes of subjects' responses. The visual records consisted of split-screen recordings of a close-up of subject's face on one half of the screen and subject's simultaneous manual responses to the stimulus array on the other, together with an accompanying sound track.

RESULTS

When the subjects were asked directly if they could find a portrait photo of themselves inserted among similar photos in the choice array of four or nine items, they had no trouble doing so with either hemisphere. Pictures of pets, other belongings and of scenes in and around the home were readily recognized by either hemisphere and evoked appropriate responses. Pictures of well-known political, historical, and religious figures, personalities of television and cinema, relatives and acquaintances plus other items in the various categories tested also were readily pointed out by the minor as well as by the major hemisphere. Responses obtained to follow-up questions after manual selection and to control

arrays with multiple familiar items indicated that the right hemisphere was not only differentiating between familiar and nonfamiliar items but was making exact identifications with which it had appropriate cognitive associations.

In addition to the correct identification of test items, appropriate kinds of emotional reactions, particularly to key items that appeared unexpectedly in an unlikely context, were evoked from the nonvocal as well as from the speaking hemispheres in both subjects. Evaluative judgments from the right hemisphere expressed by preferential pointing and by "thumbs-up"–"thumbs-down" gestures also were consistent in both cases with responses evoked similarly from the other hemisphere of the same subject or in free vision. In general, the direct vocal and pointing responses of the left hemisphere matched the manual performance of the right hemisphere, there were no instances in the test series for which it was clear that a given item was reliably recognized by one hemisphere but not by the other. If anything, the emotional responses from the right hemisphere were somewhat more intense and less restrained and qualified than those from the left. However, it is possible that this distinction may have reflected largely the added mental stress of having to use the mute hemisphere.

Minor hemisphere reactions included in particular appropriate emotional outbursts when pictures of the subject's self were introduced unexpectedly among the test items in an unseemly context. The emotional tone of these responses promptly crossed, presumably by brainstem mechanisms, and affected the vocalization of the blinded hemisphere changing the tone of voice and evoking exclamations, etc. From the contents of the left hemisphere speech, however, which included comments like "what are they?", "whatever it was", it was clear that the speaking hemisphere had remained unaware of the particular visual material that had triggered (via the mute hemisphere) the emotional outburst. When the speaking hemisphere was allowed a series of follow-up guesses, and might eventually come to ask aloud, "Was it me?", "Myself?", the recognition in the minor hemisphere of the audible stimulus as correct had a prompt central effect of some kind that registered across the midline in the speaking hemisphere, after which the vocal hemisphere accordingly settled with satisfaction on this answer as correct. Again, it was clear that the right hemisphere was making specific identifications from the responses obtained to a series of verbal cues presented by the examiner orally and sometimes visually.

A special selection of 28 of the choice array cards from the foregoing series (16 for LB, 12 for NG) were presented to LB and NG on a later occasion by PREILOWSKI and ZAIDEL [19] for correlation with recordings of associated galvanic skin and respiratory changes. The behavioral results in this repetition were qualitatively consistent and essentially much the same as those obtained in the original presentations, as described, excepting for a somewhat more facile verbal identification of the test stimuli especially by LB. This latter can be ascribed to the increased familiarity with the test cards and their content that comes with repetition. These data with the correlated GSR and respiratory findings are to be published separately.

Sample test protocols. Qualitative features of the results are best conveyed by detailed excerpts from transcripts of the test sessions with the left field of vision. A few select illustrative examples of responses from each subject are given below including full verbatim accounts of subjects' and examiners' remarks along with some brief comments on the interpretation.

Subject NG

Test A. Subject NG was presented with an array in color of four flags of England, the United States, Canada and France in that order. After subject had examined and pointed to each in turn, she was asked "Which one belongs to this country?" Subject pointed correctly to the U.S. flag. Examiner: "Which belongs to Canada?" NG pointed correctly to the Canadian flag and then did the same also for the flags of Britain and France. After correctly identifying the flags the test array was removed and subject was asked, "What was in the picture?"

NG: "Well, I can't remember, gosh."
Examiner repeated: "What was in those pictures?"
NG: "The ones he described."
Ex: "What was it?"
NG: "What describes England and all of them."
Ex: "Yes, but what is it? What kinds of things?"
NG: "The pictures, the main . . ., the main . . ., the main things."
Ex: "Was it their national . . ."
NG: Breaking in, "Yea, that's it."
Ex: Continuing ". . . *flower* or *emblem*?"
NG: "No, no, what do you call cathed . . ., cathed . . .?"
Ex: "Cathedral?"
NG: "Oh, that big thing in London. Dr. Sperry, what is that thing in London, the . . ., the what do you call it?"
Ex: "Was it the *presidents* of those countries?"
NG: "No, no . . . the Eiffel Tower."
Ex: "Was it the *flags* of those countries?"

NG then went into an abrupt silence, and said quietly in a depressed voice, "Wait a minute." and added some inaudible comments to herself.

Interpretation: By conjugate focusing mechanisms [1] the blinded hemisphere, as well as the seeing hemisphere, knows immediately which position in the test array has been focused on and selected. Bilateral motor control further allows the subject to point to a selected item with either hand. In this trial the right hemisphere recognized at least the first 3 of the 4 flags and helped direct the correct manual responses. The left hemisphere meanwhile remained uninformed of the content of the test array except for the general outlines and positions of the 4 test items and could only make guesses about the content based on the questions of the examiner and on her own oral comments and reactions. These guesses of the left hemisphere were also presumably influenced strongly by a spread across the midline of the generalized mental set or aura involved in the right hemisphere's perception and recognition of the test material. The orienting quality of the aura would probably be enough to differentiate between broad categories such as personal–impersonal, small–large, close–far, etc. and was probably responsible in this test for guesses like "the main thing," etc.

When the examiner finally asked "Was it the *flags* of those countries?" the recognition in the right hemisphere of the correctness of *flags* (and probably also of the Eiffel tower error) was transmitted immediately to the vocal hemisphere which then along with the mute hemisphere was confronted directly with the effects of her mental handicap. The simplicity and obviousness of the answer and the fact that her vocal self had made a gross error was momentarily depressing until we quickly proceeded to the next test array.

Test B. Subject was presented with a test array of 4 portrait photos of men including three strangers and one of her grown son in the upper right position. When the subject was asked, as usual, to first point in turn to each of the four pictures, she started and then paused in the process when she came to the picture of her son and said "Hey, wait a minute. That's L—— (her daughter). No that's me. No, wait a minute."

Ex: "Do you recognize one of these?"

NG: "Yes, that one right there," pointing to her son.

Ex: "OK, how do you feel about this person?"

NG: "Good, good, good. Me, when I was younger . . . or L—— (her daughter) or, or B—— (husband) . . . or I don't know." This was followed by a loud laugh and "That's it. That's gotta be," and she laughed again.

Ex: "Whatever it is, it is OK, eh?"

NG: "Yea, it's fine, it's beautiful."

Ex: "You don't see any others there that you recognize?"

NG: "No. Just that one." She pointed again to the picture of her son and said, "The best looking one there." She laughed again and said "I love me."

Ex: "Is it you? . . your husband?"

NG: No response.

Ex: ". . . your son?"

NG: "Yeah," in a very definite decisive tone after which she laughed again loudly, apparently at her prior confusions.

Interpretation: On recognition in the right hemisphere of her son's picture, the general good feeling or affective mental aura associated with this recognition crossed centrally to the left hemisphere which then made various guesses accordingly as to the source of the good personal feeling. In this case the affective aura sufficed to connote the presence of a family member or herself but did not denote the identity. As soon as the examiner mentioned her son out loud, the correctness of the central fit was immediately recognized in the right hemisphere and then in the left which then was satisfied with that as the correct identification.

Test C. Subject had just completed six trials on comparatively neutral stimuli including foods, flowers, animals, children, and people with questions centered around her special preferences, likes and dislikes, the responses to which had been relatively casual and routine. On the 7th trial we presented four portrait head and bust photos in black and white, all of the subject herself in different poses along with the impersonal instruction: "Here are four people; again, point out the one you like best."

Subject said "OK" and paused silently for about 7 sec while she examined the test array. She then burst forth with an abrupt loud exclamation: "Oh no! . . . Where'd you g . . . What *are* they?" This was followed by a very loud laugh, another exclamation, "Oh God!" and a 3 sec pause. NG than asked hesitantly, "Dr. Sperry . . . You sure there's people there?"

Ex: "Which one do you like . . . that one?" (referring to the one where subject was pointing).

NG: "Uh-huh".

On removal of the choice array examiner asked, "What was in the picture?"

NG: Still in an extra loud, emphatic voice, "Something nice whatever it was . . . Something I wouldn't mind having probably." This was followed closely by another loud laugh.

Interpretation: The loud emotional outburst at the sight of herself coming unexpectedly in this testing context is taken as strong evidence of self-recognition in the minor hemisphere, along with an added subtle sense of her own role in the testing situation. It is assumed that the emotional components of the reaction triggered in the right hemisphere crossed rapidly to the left hemisphere through brain stem mechanisms and colored the tone of speech in the vocal hemisphere. However, the content of the subject's remarks shows that the left hemisphere remained unaware of the exact stimulus material that had triggered the emotional reaction in the other hemisphere. The left hemisphere therefore could not have aided the self-recognition. The initial exclamation and comment, "Oh no . . . Where'd you g . . ." could well have come from the right hemisphere before the left had a chance to take control and exert its usual dominance over the speech apparatus. The further exclamation, "Oh God!" and the laughter could also have come from the (relatively) mute right hemisphere.

Test D. On a subsequent presentation of a similar test array of 4 pictures of herself in color this time NG again gave a somewhat similar, though less intense, response. After she had pointed to the one she liked best, NG was asked "Anyone you've seen before? Are these faces you know, or not?"

NG: "Yeah . . . do I? . . . No . . . I don't know really." After a pause she continued reflectively, "What do you think, Dr. Sperry; what's the matter with me? . . . I mean, am I thinking or what? . . k . . . keep pointing to that one, and I don't know why. Whose face is it? Probably me and that's why I like it; nobody else does. Yeah (in a more definite tone now) that's a picture of me."

Ex: "Yeah?"

NG: "Yup," firmly.

Ex: "Which one is you?"

NG: "That one (pointing to the original choice) . . . and, after a moment's pause, *that* one, . . . and *that* one . . . and *that* one (pointing to each of the other three in succession and deciding each separately).

Ex: "All four?"

NG: "Yup!" loud and definite.

Interpretation: When the vocal hemisphere, aided by various auditory cues and mainly by the affective aura generated in the right hemisphere by recognition of herself, happened to say the word "me" aloud, it was heard and perceived as correct in the right hemisphere. This produced an immediate central effect that registered across the midline and gave assurance of correctness to the vocal hemisphere also, which then asserted firmly that the four pictures were herself. The self identification in the right hemisphere which had to be inferred in test C above is directly evidenced here.

Subject LB

Test A. Subject was shown an array of four pictures of people, singly and in groups. Three of the pictures contained unknowns and one in the upper left included a picture of Hitler in uniform standing with 4 other men. LB was asked to point to "any of these that you recognize."

LB examined the card for approx 14 sec and then pointed to the face of Hitler.

Ex: "Do you recognize that one? Is that the only one?"

LB again inspected the full array but did not point to any others.

Ex: "Well, on this: is this one a 'thumbs-up' or a 'thumbs-down' item for you?"

LB: Signalled "thumbs-down".
Ex: "That's another 'thumbs-down'?"
LB: "Guess I'm antisocial." (Because this was his third consecutive "thumbs-down".)
Ex: "Who is it?"
LB: "GI came to mind. I mean . . ." Subject at this point was seen to be tracing letters with the first finger of the left hand on the back of his right hand.
Ex: "You're writing with your left hand; let's keep the cues out."
LB: "Sorry about that."
Ex: "Is it someone you know personally, . . . or from entertainment, . . . or historical, or . . . ?"
LB interrupted and said "Historical."
Ex: "Recent or . . . ?"
LB: "Past."
Ex: "This country or another country?"
LB: "Uh-huh—okay."
Ex: "You're not sure?"
LB: "Another country, I think."
Ex: "Prime Minister, king, president, . . . , any of them?"
LB: "Gee," and pondered with accompanying lip movements for several seconds.
Ex: Giving further cues: "Great Britain? . . . Germany . . . ?',
LB interrupted and said definitely "Germany" and then after a slight pause added "Hitler."

Interpretation: Right hemisphere readily identified the picture of Hitler and did not recognize any others. Left hemisphere cued by the mental aura which was generated by the picture and by the responses of the right hemisphere to examiner's questions guessed "government" and "historical," at the same time rejecting alternatives like a personal acquaintance or someone in entertainment. Subject's standard trick of trying to pass peripheral cues from the informed right hemisphere to the uninformed left was interrupted and did not help much. The continuing vagueness of the speaking hemisphere's orientation is illustrated in the hesitancy and comments like "Another country, I think." The accurate identification in the mute hemisphere is indicated in the negative responses to the series of false vocal cues and the immediate, firm positive response to "Germany" followed shortly by vocal confirmation of the correct identification of Hitler.

Test B. Subject was presented with four portrait photos of men, including three unknowns and one of Richard Nixon in the lower right.

Ex: "Out of these four, do you recognize any?"
LB looked at the 4 items for 5 sec, then pointed to the face of Nixon. He then asked hesitantly "Is it yourself?" But this vocal guess was quickly rejected when heard by the right hemisphere and LB corrected himself. "No, not either of you." In making an evaluative thumb signal he hesitated between the thumb-up position and thumb-down and finally settled on a definite neutral horizontal position with the added comment to himself "It's okay, not that good." (The date was May, 1973, prior to the full Watergate disclosure.)
Ex: "This is neutral, eh?"
LB: "Yeah."
Ex: "Who do you think it is?"

When LB could not answer examiner asked "One of your family? . . . from TV . . . or screen?"
LB started to write with his left forefinger on the back of his right hand.
Ex: "No, don't write. Historical?"
LB "No."
Ex: "Somebody here?" When subject didn't answer, examiner asked again "Historical or personal?"
LB: "Historical."
Ex: "Federal government, . . . or state?"
LB: "State, no federal."
Ex: "Minister of defense, of commerce, foreign minister, president?"
LB: "President."
Ex: "Who is it then?" (long pause) "Present, . . . past, . . . future?"
LB: "In between."
Ex: "What do you mean in between? Present or past?"
LB again didn't answer for a long period, then said "Goldwater."
Ex: "Goldwater?"
LB: "No, it's *not* Goldwater; I'm going through who it is *not*, now."
Ex: "Tell me, liberal or conservative?"
LB: "Don't quickly know."
Ex: "Democrat–Republican?"
LB: "Republican."
Ex: "Senate–House of Representatives?"
LB: "Neither."
Ex: "Any names?"

LB was not given further cues on this showing and remained unable to state vocally the name of the president.

Interpretation: Correct recognition and identification of Nixon in the right hemisphere generated associated feelings and a mental orientation which passed across to the speaking hemisphere. On the basis of this crossed affective aura combined with the left hemisphere capacity to distinguish positive and negative reactions in the opposite, mute hemisphere, plus perhaps some crude visual input through ipsilateral pathways [20], the blinded vocal hemisphere was able to reject many incorrect and affirm correct oral cues to narrow the choice accurately to "Presidents" and "Republican" and "in between" in that Nixon's status had become rather uncertain at the date of testing. In subsequent exposures the exact identification of Nixon was verbally confirmed through the left hemisphere.

Test C. LB was presented with a card containing nine 3 × 3 cm portrait photographs of women, eight strangers and one of his aunt in the lower left corner, with the instruction, "Here is a larger group of people; see if you can pick out anyone you know." Subject rather promptly pointed to his relative and indicated he did not know any others.

Ex: "On this, is this one a neutral, 'thumbs-up' or 'thumbs-down' person?"
LB made a thumbs-up signal; then smiled to himself and added "This is a happy person."
Ex: "Do you know him personally or . . . ?"
LB interrupted and said "It's not a *him*, it's a *her*."
Ex: "It's a *her*; is it entertainment, or historical . . . ?"
LB: "No, just . . ." (an indecisive pause).
Ex: "Someone you know personally . . . someone from the Late Show . . . ?"

LB: "Hmmm," and after another pause he suddenly broke through with the loud definite answer, "E——, my aunt." It was noticed that he had just been tracing something with his left index finger on the back of his right hand.
Ex: "How did you know?"
LB: "By the 'E'."
Ex: "Didn't you know before you started to write the 'E'?"
LB: "No, I came out first with 'F' and then with 'E'."
Ex: "Did you go through the letters from 'A' to 'E'?"
LB: "No, I knew by the straight line."

Interpretation: Subject's right hemisphere correctly identified his aunt and signaled a positive "thumbs-up" reaction. Transference of the affective aura enabled the vocal hemisphere to guess a "happy person" and a "her" and to reject the entertainment and historical categories. The right hemisphere tried to help by giving the left hemisphere the first letter of his aunt's name. Whether the left hemisphere was cued in peripherally by the letter traced on the skin of the right hand, or by central motor components of the writing, or by accompanying auditory images of the letter or whole name is not known.

Test D. Examiner presented an array of nine small 3 × 3 cm square color photos of women's faces including eight strangers and one of his mother in the middle row, far right.

Ex: "What is your choice here?"
LB examined the array and rather quickly pointed to that of his mother.
Ex: "Do you know who it is?"
LB: "Uh-huh," in affirmative tone.
Ex: "Can you name it? Who is it?" When subject hadn't answered after several seconds examiner added "Don't know who?"
LB: "I know who, but I can't verbalize it."
Ex: "Can you give the name?"
LB: "I know I can spell it but you won't let me spell."
Ex: "Are you sure you don't know any of the others there?"
LB reexamined the array and said "Nope."

The same test array card was repeated 20 min later and again LB pointed to the photo of his mother but could not tell us who it was. On this repetition more time and additional vocal cues were provided by the examiners as follows:

Ex: "Is this entertainment world?"
LB: "No."
Ex: "Is it historical?"
LB: "Semihistorical . . . depends on what you mean by historical, . . . historical to whom? It's mom!"
Ex: "How did you know?"
LB: "I came up with an 'M'. It wasn't Miss Montgomery, my third grade teacher, so I tried 'Mom'."
Ex: "I didn't see you write an 'M' with your hand."
LB: "I didn't."
Ex: "So, you were just thinking it?"
LB: "Yeah."

Interpretation: The right hemisphere presumably recognized his mother for whom his feelings in the last 2 yr had been very mixed. Perhaps as a consequence the kind of affective aura generated by the photo and accessible to the speaking hemisphere was not as dis-

tinctive as it might have been otherwise. At the second exposure the vocal hemisphere succeeded in the identification by what can be designated broadly as cross-cuing strategies, the mediating mechanisms of which are not clear. Apparently they involved in this case an association that combined in the left hemisphere the letter "M" with the transferred feeling that it was someone he knew well with perhaps further some feminine or even "motherly" components in the mental aura. Again it is not clear whether transfer of the letter "M" was mediated by implicit movements involved in mental writing of the letter, in subvocal speaking or through auditory images.

Test E. In preceding trials with the left visual field LB had responded with "thumbs-down" evaluations for Castro, Hitler, overweight women in swim suits, and a war scene. Intermixed with these and other responses, "thumbs-up" signals were obtained for Churchill, Johnny Carson, pretty girls, scenes from ballet and modern dance and a horizontal neutral thumb signal for Nixon as described. Toward the end of this testing session, LB was presented with a choice array containing 4 portrait photos of adult males, 3 strangers and one of himself in the lower left position. When asked if he recognized any of these LB promptly pointed to himself. Asked for a thumb sign evaluation, he gave a decisive "thumbs-down" response but unlike other "thumbs-down" signals, this one was accompanied by a wide, sheepish and (to all appearances) a self-conscious grin. When we then asked if he knew who it was, LB after only a short hesitation guessed correctly "myself".

Interpretation: LB recognized himself readily with the right hemisphere. The tongue-in-cheek "thumbs-down" response to his own photo accompanied by a broad grin indicates not only self-recognition in the minor hemisphere but also a subtle sense of humor and self-conscious perspective befitting the total situation. The emotional effect was transferred centrally and also peripherally and was sufficiently distinctive, combined with other cues, that the left hemisphere soon guessed the correct identification.

DISCUSSION

The ability of the commissurotomy subjects with visual input lateralized to the left half field to recognize, select and identify from among neutral items in a choice array pictures of themselves, their family, relatives, acquaintances, pets, belongings and also political, historical and religious figures and personalities from the entertainment world, all at a level quite comparable to that of the left hemisphere of the same subject is taken to indicate the presence in the right hemisphere of a well developed sense of self and social awareness. The kinds of emotional reactions that were generated and the selectivity of responess to follow-up questions of the examiners and to vocal cues from the subjects' own comments showed that true identifications were made in the right hemisphere accompanied by appropriate cognitive and conative associations. It was possible to exclude significant assistance from the vocal hemisphere in the initial identification process in most instances because the content of the vocal comments indicated that the speaking hemisphere had remained unaware of what the mute hemisphere had recognized and was reacting to.

The overall level of the right hemisphere's ability to identify test items and also the quality of the accompanying emotional and evaluative responses were of the same order approximately as those obtained from the right visual field and left hemisphere. Occasional discrepancies between left field and right field responses were the exception rather than the rule, did not exceed the intrahemispheric range of variation from one test session to another, and in general can hardly be considered indicative of valid left–right differences. Taken together, the present data strongly reinforce the assumption that human subjectivity is

basically much the same in the two hemispheres. It is to be expected, however, that more subtle tests than those employed in the foregoing might reveal shades of left–right differences associated, for example, with the left–right differentiation in modes of cognitive processing [21, 22]. In a more recent study with a standardized test for social-affective values in these two subjects [23] the answers obtained from the right hemisphere in both cases were more "socially conforming" to established social norms than those from the left hemisphere.

It can be argued that the kinds of functions tested above may have been acquired or greatly enhanced by extensive testing experience and related readjustments in the years following surgery in these two subjects and therefore do not reflect the typical state of right hemisphere awareness. However, some of the historical and personal items in the tests were such that the information must very probably have been acquired prior to surgery. Incidental impressions, gained from many kinds of tests applied to the minor hemisphere extending back into the early years of testing, have never given us substantial reason to doubt the existence in this hemisphere of typically human subjective awareness. Behavior after adult dominant hemispherectomy [24, 25] further favors the view that a full-fledged sense of self-awareness is present in the right hemisphere and becomes manifest as soon as recovery from the neurosurgical shock and diaschisis allows its functional expression. The observed recognition and identification of material learned years ago in school and of old family photographs, that other members of the family thought it highly doubtful the subjects had seen since their surgery, illustrated further the intactness of long term memory in both hemispheres [26]. One gains the impression that the memory system of each hemisphere at the behavioral level is more a full than a half or fractional system. This may, however, reflect in large part the role of dynamic facilitatory set factors in filling in gaps in recall in each hemisphere [27] rather than duplication in the left and right engrams. Also, it is not possible to infer that the right hemisphere memories are primarily non-verbal in view of the rather considerable ability of the right hemisphere to deal with single words [2, 28].

Uncertainties remain in regard to the extent to which subject's oral comments during testing may have come from the minor hemisphere. Judging from the general literature on aphasia and the test records of these two subjects it seems highly probable that exclamations such as "oh, no!", "wow!", "my god!", could have come from the right hemisphere, as could also single highly familiar words like "yeah", "no", "good", "uh-huh", and perhaps also longer familiar words that fit the mental set of the hemisphere and had just been spoken by the examiner, merely needing to be repeated, such as "past", "animal", "soon", "state". The suddenness with which some of these words were evoked under conditions where it was questionable that the left hemisphere would have sufficient information to provide the words directly suggests the possibility of right hemisphere participation (see also [28 and 29]). In general it remains to be determined, however, how both subjects were able to respond so quickly to signify a correct identification upon hearing a correct vocal cue coming either from the examiner or from their own oral guesses and comments. With each hemisphere mentally searching for the answer, the right hemisphere, needing a correct word or name to express what it has recognized visually and the left needing something more specific as a focus for the vague mental aura that transfers, a correct oral cue could have instant resolving effects in both hemispheres which would be rapidly finalized The evidence to date seems to favor the view that the right hemisphere is very importantly involved in processing the verbal cues. However to untangle the various alternative possible mechanisms that may be at work will require more analytic data than is currently available.

Questions remain also about the nature, mechanisms and functional role of the emotional and mental aura generated by the perception and recognition of a key test item. At least large components of the aura seemed to spread readily to the opposite hemisphere presumably through brain stem systems. In addition to general emotional changes the central transfer appeared to include also subtle cognitive effects that enabled categorical distinctions like those between government and personal, domestic vs foreign, historical vs entertainment, etc. Common experience suggests that such emotional and conative auras play an important orientational role in normal brain function as, for example, in mnemonic retrieval.

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REFERENCES

1. SPERRY, R. W. Mental unity following surgical disconnection of the cerebral hemispheres. *The Harvey Lectures*, Series 62, pp. 293–323, Academic Press, New York, 1968.
2. SPERRY, R. W., GAZZANIGA, M. S. and BOGEN, J. E. Interhemispheric relationships: the neocortical commissures; syndromes of hemisphere deconnection. In *Handbook of Clinical Neurology*, P. J. VINKEN and G. W. BRUYN (Editors), Vol. 4, Chapter 14, pp. 273–290. North Holland, Amsterdam, 1969.
3. SPERRY, R. W. Forebrain commissurotomy and conscious awareness. *J. Med. Philos.* **2**, 1–21, 1977.
4. ECCLES, J. C. Brain, speech and consciousness. *Die Naturwissensch.* **60**, 167–176, 1973.
5. ECCLES, J. C. *The Understanding of the Brain*. McGraw-Hill, New York, 1973.
6. MACKAY, D. M. Discussion. In *Brain and Conscious Experience*, J. C. ECCLES (Editor), pp. 422–444, Springer, Heidelberg. 1966.
7. WIGAN, A. L. *The Duality of the Mind*. Longman, London, 1844.
8. BOGEN, J. E. The other side of the brain—II. An appositional mind. *Bull. Los Angeles Neurol. Soc.* **34**, 135–162, 1961.
9. PUCCETTI, R. Brain bisection and personal identity. *Brit. J. Philos. Sci.* **24**, 339–355, 1973.
10. PUCCETTI, R. The mute self. A reaction to DeWitt's alternative account of the split-brain data, 1976.
11. NAGEL, T. Brain bisection and the unity of consciousness. *Synthese* **22**, 396–413, 1971.
12. ZANGWILL, O. L. Consciousness and the cerebral hemispheres. In *Hemisphere Function in the Human Brain*, S. DIMOND and J. BEAUMONT (Editors). Paul Elek, London, 1974.
13. DEWITT, L. Consciousness, mind and self: The implications of the split-brain studies. *Brit. J. Philos. Sci.* **26**, 41–47, 1975.
14. GALLUP, G. G. Self-recognition in primates. *Amer. Psychol.* **32**, 329–338. 1977.
15. AMSTERDAM, B. Mirror self-image reactions before age two. *Devl. Psychobiol.* **5**, 297–305, 1972.
16. SPERRY, R. W. and ZAIDEL, E. Level of consciousness in the surgically disconnected minor hemisphere. *Proc. 14th Annual Meeting Psychonomic Society* (Abst.), 1973.
17. BOGEN, J. E. and VOGEL, P. J. Neurological status in the long term following complete cerebral commissurotomy. In *Les Syndromes de Disconnexion Calleuse Chez L'Homme*. Hopital Neurologique, Lyon, 69394, 1976.
18. ZAIDEL, E. A technique for presenting lateralized visual input with prolonged exposure. *Vision Res.* **15**, 283–289, 1975.
19. PREILOWSKI, B. Consciousness after complete surgical section of the forebrain commissures in man. 1977 EBBS (in press).
20. TREVARTHEN, C. and SPERRY, R. W. Perceptual unity of the ambient visual field in human commissurotomy patients. *Brain* **96**, 547–570, 1973.
21. LEVY-AGRESTI and SPERRY, R. W. Differential perceptual capacities in major and minor hemispheres. *Proc. natn. Acad. Sci., U.S.A.* **61**, 1151, 1968.
22. LEVY, J., TREVARTHEN, C. and SPERRY, R. W. Perception of bilateral chimeric figures following hemisphere deconnection. *Brain* **95**, 61–78, 1972.
23. ZAIDEL, E. Unpublished data.
24. SMITH, A. Speech and other functions after left (dominant) hemispherectomy. *J. Neurol. Neurosurg. Psychiat.* **29**, 467–471, 1966.
25. ZAIDEL, E. Auditory vocabulary in the right hemisphere following brain bisection and hemidecortication. *Cortex* **12**, 191–211, 1976.
26. ZAIDEL, D. and SPERRY, R. W. Memory impairment after commissurotomy in man. *Brain* **97**, 263–272, 1974.

27. SPERRY, R. W. In search of psyche. In *Paths of Discovery*, E. WORDEN, J. SWAGY and G. ADELMAN (Editors). MIT Press, Cambridge, 1975.
28. BUTLER, S. R. and NORRSELL, U. Vocalization possibly initiated by the minor hemisphere. *Nature, Lond.* **220**, 793–794, 1968.
29 LEVY, J., NEBES, R. D. and SPERRY, R. W. Expressive language in the surgically separated minor hemisphere. *Cortex* **7**, 49–58, 1971.

Résumé :

On a examiné 2 malades ayant subi une commissurotomie cérébrale en latéralisant les entrées visuelles à la moitié droite ou gauche du champ visuel par un écran opaque sur l'hémichamp établi dans le plan focal d'un système optique monté sur une lentille de contact permettant des expositions prolongées et un balayage oculaire de dispositifs visuels complexes. On a présenté à ces sujets des stimulus à références personnelles et affectives en même temps que des items permettant de s'assurer de leurs connaissances sociales générales parmi d'autres items neutres et inconnus d'eux, dans des présentations de 4 à 9 choix. Les réponses manuelles et émotionnelles associées obtenues à partir de l'hémisphère mineur à des représentations du sujet lui même ou de ses proches, d'animaux et d'objets familiers, de personnalités publiques, historiques et religieuses ainsi que de personnalités appartenant au monde du spectacle révélaient une conscience de soi et une conscience sociale et politique en gros comparables à celle de l'hémisphère majeur du même sujet.

Deutschsprachige Zusammenfassung:

Zwei Patienten mit cerebraler Commissurotomie wurden getestet mit visuellen Reizen, die in der linken oder rechten Gesichtsfeldhälfte dargeboten wurden. - Die Reizdarbietung erfolgte auf einer undurchsichtigen Halbfeld-Leinwand in der Brennebene eines optischen Systems, das auf einer Sklera-Kontaktlinse angebracht war und Langzeitdarbietung, sowie okuläres rastermässiges Abtasten (Scanning) von komplexen visuellen Arrangements erlaubte. Persönliche und affektbesetzte Schlüsselreize, zusammen mit Items zur Einschätzung des allgemeinen sozialen Verständnisses wurden dargeboten zwischen neutralen unbekannten Items im visuellen Arrangements mit 4 - 9 Wahlmöglichkeiten. Die selektiven manuellen und entsprechenden emotionalen Antworten, die von der nicht dominanten Hemisphäre auf Bilder der Versuchsperson selbst, seiner Angehörigen, Haustiere und ihm gehörender Gegenstände sowie von öffentlichen, historischen und religiösen Figuren und Persönlichkeiten der Unterhaltungsszene erhalten wurden, zeigten eine charakteristische soziale, politische, persönliche und Selbsteinschätzung, die im groben derjenigen der dominanten Hemisphäre beim gleichen Individuum entsprach.